New Zealand Antarctic Research Programme

Antarctic Weather

Antarctic Division, DSIR

Christchurch New Zealand

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Published by: Antarctic Division
D.S.I.R.
P.O. Box 13-247
CHRISTCHURCH

Antarctic Division, DSIR gratefully acknowledge the contribution made by the New Zealand Meteorological Service in respect of the editorial content of this publication.

ANTARCTIC WEATHER

Antarctica is the coldest, windiest, and driest continent on Earth. Biting cold, high winds and blinding snow occasionally make life both uncomfortable and dangerous. These harsh climatic facts were well-known to the early explorers, who suffered many tragic losses to the elements. Today, despite improved technology, comfort and activity is still limited by an inhospitable environment.

Temperatures

Antarctica holds the world record for low temperatures — a chilling -88.3° at Vostok in the central part of Greater Antarctica. In many inland areas of the high polar plateau the thermometer seldom climbs above -50° for six months of the year. At these cold temperatures, frostbite of exposed parts can occur in seconds and special precautions are necessary to avoid freezing of the air passages. Normally flexible materials such as rubbers and plastics can crack or shatter like glass, and fuel oil freezes to a jelly.

The primary reason for the extreme cold of the Antarctic is the small amount of incoming solar energy absorbed near the surface. During winter, the solar input is negligible. Even in summer, the sun's radiation is received at the surface at a very oblique angle. Of this energy, less than a quarter goes toward heating the surface. The remaining three-quarters is reflected by the white snow surface, which is also continuously losing heat by radiation. Because of the great clarity of the air, much of this outgoing radiation is lost to space, especially over the elevated plateau. Thus, except for a few weeks in mid-summer, Antarctica is continually losing heat by radiation. The reason that the temperature doesn't plummet to absolute zero in winter is that this radiational deficit is balanced by the transport of air from warmer latitudes. This balance prevents the temperature from continuing to fall during the long winter night, exhibiting the so-called "Kernlose" (coreless) winter phenomenon. Because the snow surface loses heat more efficiently than air, the atmosphere tends to be cooled from below. This results in a surface layer of cold air in which the temperature rises with increasing elevation. This inversion, as it is called, is an important feature of the Antarctic temperature regime. Over the continental plateau, the air temperature 1000 metres above the surface can be as much as 40°C warmer than at the surface. In the McMurdo area, the inversion is seldom more than 10°C in strength.

Near the coasts where the ocean exerts a moderating effect, winter minimum temperatures seldom drop below -40°C. Summer

Table I: Temperature data (°C) for Scott Base (1957 - 79), McMurdo (1957 - 77), and Hut Point (1902 - 04).

SCOTT BASE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
Mean Temperature	-4.9	-10.8	-20.4	-24.2	-27.4	-26.2	-29.4	-31.0	-28.1	-22.7	-12.0	-5.4	-20.2
Mean Daily Max	-1.4	-7.2	-15.9	-18.9	-21.2	-20.1	-23.1	-24.3	-21.9	-17.6	-7.6	-2.0	-15.2
Mean Daily Min	-8.5	-14.3	-24.9	-29.5	-33.7	-32.2	-35.7	-37.6	-34.2	-28.4	-16.4	-8.9	-25.4
Mean Monthly Max	+3.6	-0.9	-6.3	-8.3	-9.6	-10.5	-11.0	-11.7	-11.7	-7.1	-1.7	+2.7	+4.1
Mean Monthly Min	-14.9	-23.1	-36.8	-41.8	-45.5	-44.1	-48.1	-50.3	-46.9	-40.7	-25.9	-15.5	-52.6
Extreme Maximum	+6.8	+5.0	-2.0	-4.6	+0.2	-4.8	-4.2	-2.7	-3.3	-0.2	+1.3	+5.8	+6.8
Extreme Minimum	-19.7	-30.2	-44.6	-50.4	-53.2	-52.2	-54.2	-56.6	-57.0	-52.0	-37.2	-22.8	-57.0
Mean Daily Range	7.1	7.1	9.0	10.6	12.5	12.1	12.6	13.3	12.3	10.8	8.8	6.9	10.2
McMURDO													
Mean Temperature	-2.8	-8.4	-17.6	-21.3	-23.8	-23.2	-26.1	-27.8	-24.8	-19.9	-9.5	-3.4	-17.4
Mean Daily Max	-0.3	-5.8	-14.4	-17.9	-20.0	-19.3	-22.0	-23.4	-20.6	-16.2	-6.6	-1.0	-14.0
Mean Daily Min	-5.4	-10.9	-20.6	-24.8	-27.6	-27.1	-30.2	-32.1	-28.9	-23.7	-12.5	-5.8	-20.8
Extreme Maximum	+8.3	+3.9	-2.2	-3.9	-2.8	-4.4	-4.4	-4.4	-8.3	-4.4	+2.8	+9.6	+9.6
Extreme Minimum	-15.6	-23.9	-43.3	-39.4	-44.4	-41.1	-50.6	-49.4	-43.9	-40.0	-28.3	-16.7	-50.6
Mean Daily Range	5.1	5.1	6.2	6.9	7.6	7.8	8.2	8.7	8.3	7.5	5.9	4.8	6.8
HUT POINT													
Mean Temperature	-4.4	-8.9	-15.8	-24.4	-25.9	-26.1	-26.0	-26.9	-26.3	-22.1	-10.3	-4.1	-18.4
Mean Daily Max	-0.8	-6.9	-12.6	-20.4	-21.8	-21.1	-21.6	-22.3	-21.9	-18.4	-7.0	-0.9	-14.7
Mean Daily Min	-7.8	-14.4	-19.7	-29.4	-31.7	-32.6	-32.3	-33.3	-32.1	-27.2	-14.3	-7.6	-23.6
Mean Daily Range	7.0	7.5	7.1	9.0	9.9	11.5	10.7	11.0	10.2	8.8	7.3	6.7	8.9

temperatures usually remain a few degrees below 0ºC, although summer maxima as high as 8ºC are not uncommon. Such conditions are typical of the Scott Base — McMurdo area, summarized in Table 1. The warmest summer temperatures are found in the Dry Valley area, where the ice-free surface absorbs most of the incoming solar radiation. At Vanda, a high of 15ºC has been recorded.

Wind and weather

Of the weather elements, wind is probably the major factor limiting activity and comfort in the Antarctic. One reason is that heat loss from the body is enhanced in windy conditions. Antarctic clothing must not only conserve body heat, but also allow minimum penetration by the wind in order to reduce this wind chill factor. Table 2 shows how the effective temperature "felt" by the body decreases dramatically as the wind speed increases.

Another wind-related factor that interupts outdoor activity is blowing snow. Blowing snow occurs with winds in excess of about 10 metres per second (19 kt). Strongf wind picks up loose snow from the surface, reducing visibility. Winds stronger than about 15 metres per second (28 kt) reduce visibility to near zero, making outdoor activity extremely dangerous. Blowing snow is slightly less of a problem during the warmest part of the summer because some melting and consolidation of the surface layer of snow occurs. In the Scott Base area, blowing snow occurs on about 4 days per month during summer (November to February), but averages 13 days per month during the remainder of the year. Visibility below 5 nautical miles occurs about 25% of the time in winter and 10% in summer.

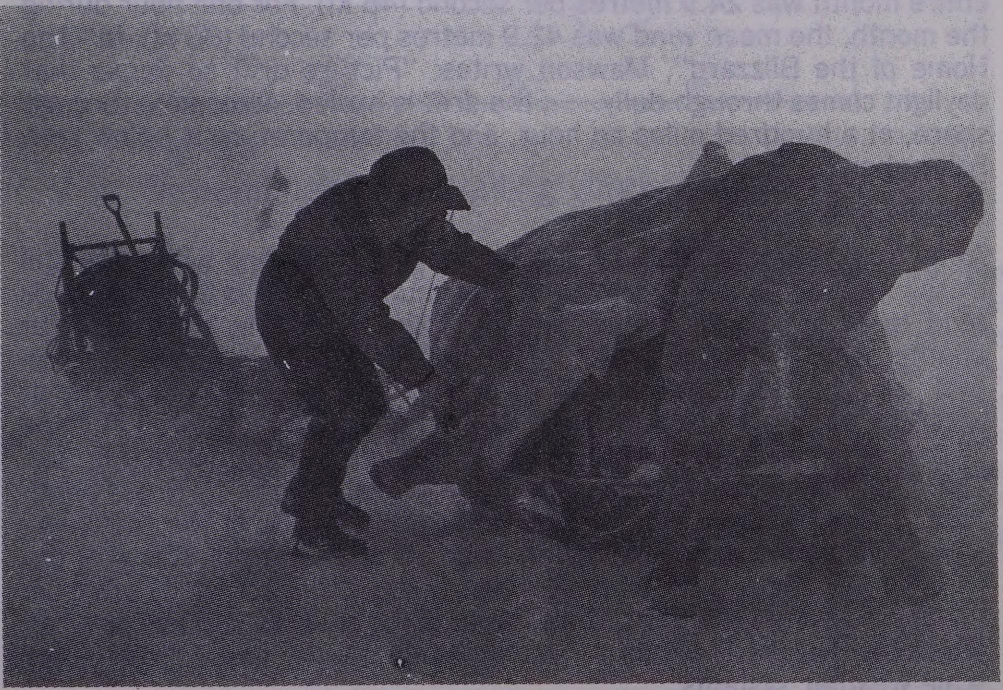
Further statistics for various weather elements at Scott Base and McMurdo are summarised in Table 3. Note that autumn is the cloudiest and snowiest season. Fog occurs at Scott Base about 1-2 days per month on average. When it occurs, especially in the summer months, it leaves behind a beautiful deposition of ice crystals on aerials and superstructure. Rain is extremely rare — it has been observed at Vanda on one or two occasions, and at more northern Antarctic stations.

Table II: Mean cloud cover and frequency occurrence of the various weather elements shown for Scott Base (1957 - 79 data) and McMurdo (1956 - 72). McMurdo data are from climatological summaries prepared by NOAA. (Except for blowing snow and low visibility data which are from Thompson (1972).)

SCOTT BASE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
Cloud Cover (Octas)	5.0	6.0	5.7	5.3	4.3	4.2	3.8	4.2	4.7	4.4	4.4	4.9	4.8
Days of Snow	6.9	8.3	7.1	6.0	5.8	5.2	5.0	4.2	4.8	5.5	6.3	7.3	72.4
Days of Fog	2.0	1.0	1.3	1.4	0.7	1.0	2.0	2.2	2.6	1.4	0.3	1.0	16.9
McMURDO													
Cloud Cover	5.0	6.1	5.9	4.4	4.7	4.1	4.0	3.9	4.6	4.6	4.6	5.0	4.7
Days Blowing Snow	2	3	11	14	12	14	13	11	16	10	4	3	9.4
Freq. of Snow (%)	10	19	17	19	18	19	16	19	15	13	11	13	16
Freq. of Fog (%)	2	1	4	4	3	2	2	3	2	3	1	2	2
Freq. Vis. 2nm (%)	3	4	12	14	13	16	13	12	17	11	4	5	10
Precipitation (mm water equiv)	19	28	16	13	14	23	10	16	12	12	11	15	188

Blizzards

Occasionally, blizzards bring all activity to a halt, often for several days at a time. These "herbies", as they are affectionately known, are accompanied by gale force southerly winds and zero visibility. Such storms are usually, but not always, associated with a cyclonic centre several hundreds of miles east or northeast of McMurdo. In the McMudo area, visual clues such as lenticular (lens-shaped) cloud formations over the mountains to the south and the obscuration of Minna Bluff in low stratus cloud are sometimes the first indication of deteriorating weather. Clouds of blowing snow to the south often herald a change to blizzard conditions. The wind is usually squally at its onset, rising rapidly to maximum speed, then decreasing gradually over an hour or so, or until the next squall. In winter, the first gust of wind is often accompanied by a sharp rise in temperature as the stagnant surface cold layer is swept away. Strong local variations frequently occur — it is not uncommon to have blizzard conditions prevail at one site while a nearby location enjoys lighter winds. Blizzards may or may not be accompanied by precipitation, although the difference between falling and blowing snow is usually academic! As noted earlier, strong winds and blizzards are most severe during the winter months, but can occur at any time of year.



An important characteristic of the Antarctic wind regime is its close dependence on terrain. Over the gentle slopes of the inland polar plateau, the air flows downslope with remarkable constancy in a direction about 45° to the left of line of maximum terrain slope. This comes about as a result of the strong cooling of the lowest layers of the atmosphere which results in a layer of cold, dense air in contact with the surface. This air moves downhill under the influence of gravity, and is deflected to the left by the Earth's rotation. Continual cooling replenishes the supply of cold air and maintains a steady drainage of cold air off the polar plateau.

Katabatic Winds

Near the edge of the polar plateau, the terrain slopes more steeply toward the coast, and the cold air drains more rapidly. The violent winds that result are called katabatic winds (although, strictly speaking, any downslope wind can be classed as katabatic). At onset, the wind jumps from near calm to 15-20 metres per second (30-40 kt) or more. Because the cold air drains away in a sudden rush, these katabatic winds are more spasmodic than their plateau counterparts. Certain locations are particularly prone to katabatic winds. Cape Denison, home of Sir Douglas Mawson's Australasian Antarctic Expedition, is probably the windiest location on Earth. In July, 1913, the mean wind speed for the entire month was 24.9 metres per second (46 kt). For one hour during the month, the mean wind was 42.9 metres per second (80 kt). In "The Home of the Blizzard", Mawson writes: "Picture drift so dense that daylight comes through dully . . .; the drift is hurled, screaming through space, at a hundred miles an hour, and the temperature is below zero Fahrenheit."

Prevailing Winds

Away from the polar plateau, the patterns of prevailing winds are still closely related to the terrain. A rule of thumb is that prevailing winds tend to blow parallel to the local contours of terrain elevation. Put another way, this means that the air prefers to go around rather than over islands, mountains etc. in its path. Thus, the prevailing flow at Scott Base is from the northeast, while that only 80 km away at Cape Crozier at the eastern end of Ross Island is from the southwest (Fig. 1a). The difference is due to deflection of the prevailing flow by Ross Island. Fig. 1a may be used to determine the likely direction of the prevailing wind at locations near Ross Island. Fig. 1b shows the direction of the wind flow in blizzard conditions — clearly the strongest winds are from the south at most locations. Ross Island is too small to support strongly developed katabatic winds — strong winds usually result from larger scale weather systems.

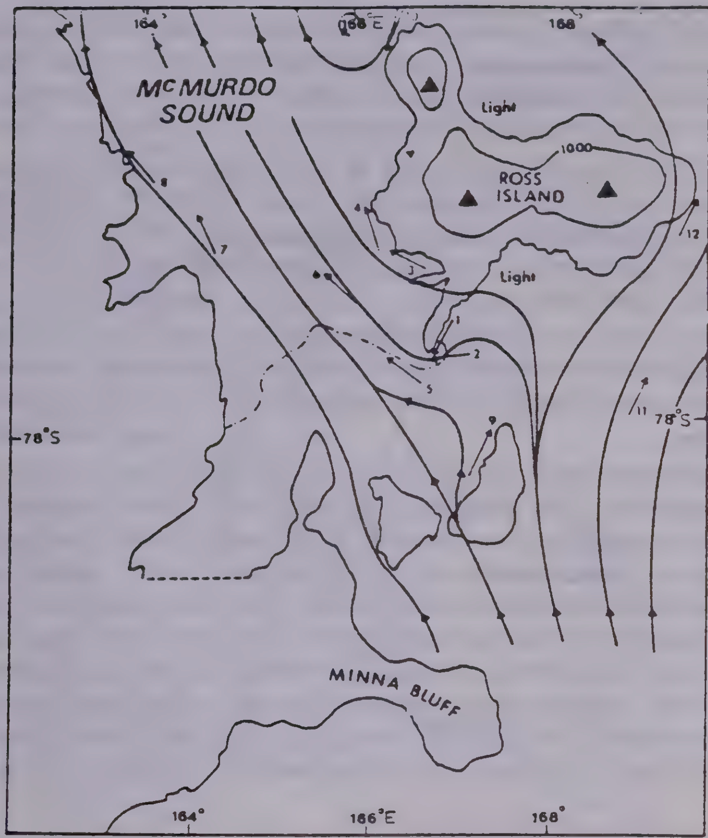


Fig. 1a
Streamlines of prevailing winds, Ross Island.

At Scott Base, the prevailing wind is from the northeast. Winds from the narrow sector between 010 and 040 degrees true blow about 60% of the time. The average annual wind speed is about 6 metres per second (11 kt). During summer, slightly lighter winds prevail. In winter, wind gusting to over 18 metres per second (33 kt) occurs on average about 11 days per month, compared with only 3 days in summer (November to February). Virtually all these strong winds are from the south. Gusts over 28 metres per second (51kt) occur about 3 kdays per month in winter, but only 0.2 days monthly in summer. It is calm about 14% of the time annually.

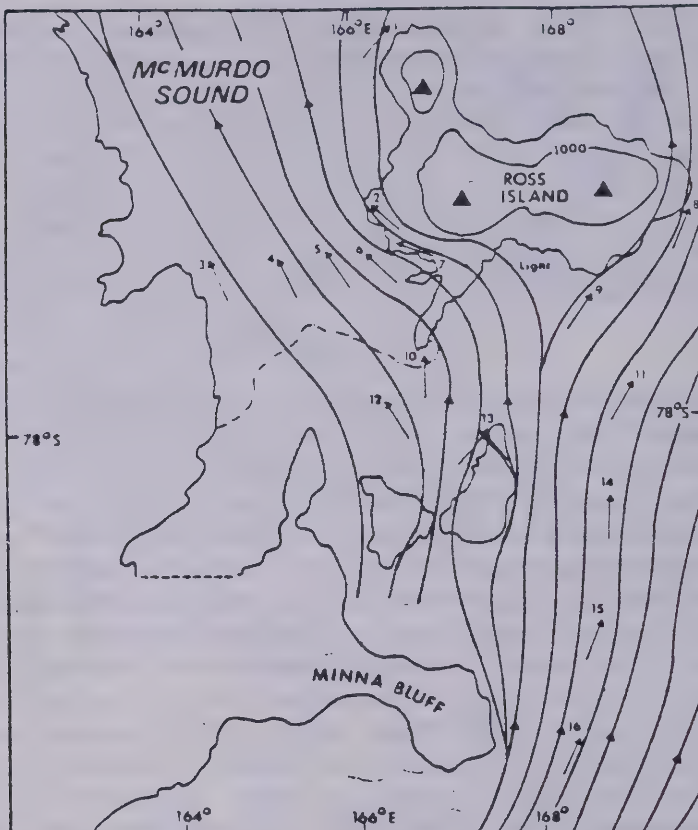


Fig. 1b

Streamlines of blizzard winds, Ross Island. (Adapted from a similar figure by G.C. Simpson "British Antarctic Expedition 1910-1913. Meteorology, Vol. 1. Discussion," 1919)

Areas near the edge of the continental plateau exhibit localised valley circulations. In the Dry Valleys, there is a marked daily cycle of wind in summer. Easterlies blow inland during the day, reaching a maximum in mid-afternoon, then decreasing to a minimum early in the morning, or even turning to the west. Thus the hours midnight to 6am are often the most comfortable for outside activity. Winter in the Dry Valleys is characterised by lengthy calm spells followed by violent westerly gales. These westerlies are relatively warm, and extremely dry. They are often accompanied by blowing grit and sand. Dust and snow whirls have occasionally caused considerable damage to outside stores and base buildings at Vanda station. These vortices reach heights of 100-200 m, and transport vast quantities of sand, grit and small stones. Larger,

tornado-like vortices have been observed. During westerly gales, static charges build up on radio antennae, sometimes causing damage to electronic equipment. Clouds of blowing snow on the polar plateau to the west provide reliable advance warning of these westerly storms.

One important characteristic of the Antarctic climate that cannot be overemphasised is the highly local and variable nature of the weather. Calm conditions at Scott Base do not mean calm conditions at a field site 20 km away. Furthermore, the weather can change quickly. A temperature of -20°C with no wind is vastly different from -20°C and a moderate breeze. Blizzards can develop beneath a perfectly clear sky. In open, snow-covered areas, disorientation due to whiteout can occur if the sky becomes overcast. Workers in the field need to be prepared for these sudden changes.

In spite of the many colourful descriptions of the Antarctic blizzard, the Antarctic climate is not one of continual freezing fury. Most areas enjoy the prevalence of clear or partly cloudy skies and moderate winds. parts of the Dry Valley "Oasis" sometimes enjoy mid-summer temperatures above 10°C, which is warm enough to create streams of melt-water from nearby glaciers. Precipitation is comparable to that of a typical desert — in fact Antarctica is the driest of the Earth's continents. The dry, dust-free air yields views of the ice-covered grandeur that are of exceptional clarity. During calm conditions the great stillness and beauty provide an experience that stands in striking contrast to the howling blizzard.

Whiteout

One particularly insidious Antarctic hazard that deserves special comment is whiteout. This is an optical phenomenon that occurs in uniformly overcast conditions over a snow-covered surface. It is associated with diffuse (uniform), shadowless illumination which causes a lack of surface definition and reduced horizon definition. The effect has been likened to being inside a milk bottle. Because our ability to perceive snow-covered topographic features depends on the shadows that they cast, such forms become indistinguishable under whiteout conditions. Without any visual stimulation it is common to incorrectly evaluate an incline (i.e., one may walk up and down hills without realising it). Furthermore, it is known that an individual attempting to follow a straight path unaided will veer. Judgements of the distance and orientation of objects in the field of view is severely handicapped. Such spatial disorientation is enhanced inside a moving vehicle. Whiteout conditions can occur while visibility (i.e., the transparency of the air) remains good. Partially reduced horizon and surface definition can occur under a broken cloud layer.

Sunlight hours

In the polar regions there are tremendous variations during the year in the amount of sunlight, ranging from 24 hour sunlight in summer to 24 hour darkness in winter. These variations have a profound effect on the lives of the inhabitants of these regions.

In winter, the sun remains below the horizon for most of the time. South of the Antarctic circle (67.5ºS), the sun remains entirely below the horizon in mid-winter. At the South Pole, the sun is below the horizon for six months in winter and above it for six months in summer, separated by a two week twilight. At the latitude of Scott Base (78º), the sun is entirely below the horizon between late April and mid August. There is complete darkness between mid May and late July. By late October, the sun is entirely above horizon again, remaining so until early February.

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